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INSTALATION OF LINE REPLACEABLE UNITS INTO THE NATIONAL IGNITION F ACILITY

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ABSTRACT

In the National Ignition Facility (NIF), currently under design and construction at Lawrence Livermore National Laboratory (LLNL), 192 high-power laser beamlines incorporating over 8,000 large optics, will be focused onto a target smaller than a dime. The actual laser path will be contained within the Laser Target Area Building (LTAB), but the smaller adjacent building, the Optics Assembly Building, will be where the optic modules are assembled and aligned. After the optics are finished in the OAB they must be transported and installed into the LTAB. While this is done strict cleanliness and handling conditions must be maintained. To maximize the efficiency of this process the optics are assembled into Line Replaceable Units (LRUs), which typically consist of a mechanical housing, laser optics, utilities, actuators and kinematic mounts. In this paper the Optical Transport and Material Handling designs that will be used to deliver the LRUs into the NIF laser bays are presented.

Five types of delivery systems have been developed to deliver the LRUs to their locations in the LTAB. They are top loading, bottom loading, side loading, switchyard loading and target area loading. The first three operate in the laser bay of the LTAB and are transported between the OAB and the LTAB by the Laser Bay Transport System (LBTS). All delivery systems must maintain each optical LRU assemblies' specified shock, vibration, cleanliness, and environmental requirements. The design for each delivery system must take into consideration the cleanliness, functionality and alignment of the LRUs while maximizing commonality in order to meet the beamline installation schedule. This paper focuses on the design challenges of the bottom, side and top loading delivery systems and especially on how commonality amongst these varied systems is achieved.

1. Introduction

The U.S. Department of Energy (DOE) is currently building the National Ignition Facility (NIF). The NIF is an advanced, high-power laser facility for inertial confinement fusion (ICF) research and applications1. This facility is expected to reach fusion ignition and to make significant contributions to DOE's Defense Programs Stockpile Stewardship mission. The NIF has two primary buildings: the Optics Assembly Building (OAB) and the Laser and Target Area Building (LTAB). The OAB provides the facilities necessary for assembling and aligning the components that make up the optical path of the laser. The LTAB, the size of a stadium, houses the laser system and the spherical target chamber.

The design philosophy for the NIF is to modularize the laser optical components. Each laser component is packaged into a line-replaceable unit (LRU), which allows efficient, safe, and cost-effective assembly, transportation, installation, and removal. An LRU typically comprises a mechanical housing, laser optics (lenses and mirrors), utilities, actuators, and kinematic mounts. Most LRUs are assembled and aligned in the OAB with LRU subcomponents being processed as needed. The NIF project's Optical Transport and Material Handling team is developing the systems that deliver the LRUs to the beamline. The delivery systems, shown in Figure 1, provide the methodology and equipment necessary for transporting the optical LRU assemblies between their installed positions and maintenance/assembly facilities, as well as installing and removing them.

Commonality in transporting the bottom-, top- and side-loading systems is obtained by use of a commercially provided Auto-Guided Vehicle (AGV), shown in Figure 2, called the Laser Bay Transporter (LBT). By using laser-guidance position updates in conjunction with an inertial guidance system the transporter can move autonomously between the OAB and the LTAB. The transporter carries the bottom-, top- and side-loading delivery systems on two interface plates, shown in Figure 3, mounted to the top of the forks. Each interface plate can be moved separately fore/aft by 2" on top of its fork. The forked platform can move from side to side by 2" and can rotate about a vertical hinge axis located between the load and the transporter lift axis. The interface plate includes several load-mounting points (pin/cone combinations) for handling the bottom loading canister, the top loading canister and the side loading skid.

2. Bottom-loading delivery system

The bottom-loading delivery system handles over 2,700 individual bottom-loaded LRUs with three different canister designs: an amplifier-slab configuration, a flashlamp configuration and a "universal" configuration. All three types of bottom-loading canisters are carried on the same load mounting points on the interface plate mounted to the top of the forks of the LBT (see Figure 3). The pickup, transport, and docking procedures for each bottom-loading canister are also similar. The LBT picks up the canister from a support stand in the LTAB/OAB corridor then transports the canister into the basement of the OAB where the canister is docked to the ceiling, or floor of the OAB. Here an LRU is lowered into the canister. The LBT then transports the canister back up to the LTAB and, finding the right LRU placement location underneath the laser enclosure, docks the canister up against the bottom of the enclosure. Final placement during docking and precise alignment of the canister relative to the laser enclosure is accomplished with the transporter's fine positioning system[2].

Once the canister is securely docked, the internal canister mechanisms activate to install the LRU into the laser. Three different types of installation processes can be employed: single-stage, two-axis and multistage. The differences arise only in the direction of travel or in the travel length over which the LRU needs to be moved when being inserted. There are many identical steps, the first of which is inflation of the flexible seal (pneuma seal), sealing the canister to the laser enclosure. Second, the HEPA airflow system starts up and flushes out any debris generated by the insertion mechanisms from inside the canister volume. Third, the cover-removal mechanism removes both the canister cover and the beamline cover in a Smith-type fashion. Fourth, the vertical ballscrew insertion mechanism lifts the LRU (or LRU and spacers) to a position inside the laser at which the LRU's kinematic mounts can latch. Fifth and finally, the insertion mechanism lowers the LRU onto kinematic mounts in the laser to complete the LRU installation process.

After the LRU is placed, the insertion mechanism continues to lower the empty carriage back into the canister. The cover-removal mechanism reinstalls both covers and the pneuma seal is deflated. The transporter then lowers the empty canister off the ceiling, lowers itself off of its leveling jacks then transports the canister back to the OAB.

3. Top loading delivery system

Commonality in the top and bottom loading delivery systems is preserved by use of the same transporter, and interface plate and the same general design philosophy. In many ways the top loading delivery system design is bottom loading "standing on its head" with some differences in mechanization. The top loading canister also represents a clean room for transport of the NIF laser LRUs. It incorporates a HEPA airflow system to scrub the internal volume of the canister during the LRU insertion process. It utilizes a cover removal mechanism to remove the covers of both the canister and the laser enclosure in a Smith-type fashion.

Differences arise in the method of docking and in the direction of insertion of the LRU into the laser. Docking is achieved by a crane, which transfers the top-loading canister off the transporter and places it on top of the center vessel of the cavity or transport spatial filter of the NIF laser. Once the canister is docked, sealed and open, the canister insertion mechanism lowers the LRU onto kinematic mounts inside the laser. With the LRU inserted, the ballscrew drive retrieves the empty carriage back into the canister. The covers of both the canister and the laser enclosure are replaced and the canister is removed and placed onto the transporter by the crane.

The empty top-loading canister is returned to the OAB where another crane lifts it off the transporter and places it onto the OAB loft. A sequence of actions similar to that used in docking to the laser structure is now used to dock the top-loading canister to the OAB ceiling, open the canister and OAB loft port and reload the canister with an LRU prepared in the OAB.

4. Side loading delivery system

The side loading delivery system is similar to bottom loading and top loading in that it uses the laser bay transporter. That is where similarities end, due to significant differences in the LRU being delivered. The side loading LRU: the Preamplifier Module (PAM) is a completely enclosed laser amplifier system. It doesn't need to be transported inside a clean room environment or inserted into the clean laser enclosure like the LRUs delivered with the bottom and top loading delivery systems. The PAM, containing its own guide rollers, is placed and connected to the NIF laser by placing it on guide rails in the Preamplifier Support Structure (PASS) and rolling it into its final position in the NIF laser.

A mechanized skid is used to transport and place the PAM onto the laser support structure. This skid is used to first transport the PAM out of the Preamplifier Maintenance and Alignment (PAMMA) room in which the PAM is assembled and tested.

After transport out of the PAMMA room into the LTAB corridor, the side-loading skid is picked up by the LBT. The second set of mounting points from the right end of the interface plate (see Figure 3) is used to locate the skid onto the transporter's motorized load platform. With the 5-meter skid and PAM on the load platform, the transporter drives along the PASS carrying the skid sideways and stops at the appropriate PAM loading site. There the transporter drives sideways (thereby moving the skid forwards toward the PASS) until the end of the skid is 2" from the PASS face. Once there the transporter levels itself with its leveling jacks, then lifts the skid to the nominal docking height and, using a vision feedback system, adjusts the skid position and orientation to match the docking interface. Range sensors on the front of the skid are used to verify that the skid docking pins are within their capture range. The skid is then raised 6" above its docking height, and the two skid docking pins are deployed to a distance determined by the range sensor readings. The docking pins fit into two keyhole slots in the PASS as the skid is slowly lowered to its docking height. Feedback from a tilt sensor on the skid is used to stop the transporter lift such that the skid is level to the PASS face. At this point the most of the weight of the skid is supported on one end by the docking pins in the PASS and on the other end by one fork of the transporter load platform. The transporter fine positioning system is used to move the supported point on the skid fore/aft on the fork until the range sensor feedback indicates that the skid is perpendicular to the PASS face. During this operation the interface plate on the fork closer to the PASS is in a back-drive mode[2] thereby providing the needed compliance at this point. Once docked a trolley on the skid drives the PAM forward into the PASS using guide rails on the skid and PASS. Retrieval of the PAM is the reverse of the process described

Conclusion

We have described how commonality is incorporated into the design of the NIF laser bay LRU delivery systems and have detailed the operation of the bottom-loading, top-loading and side-loading operations.

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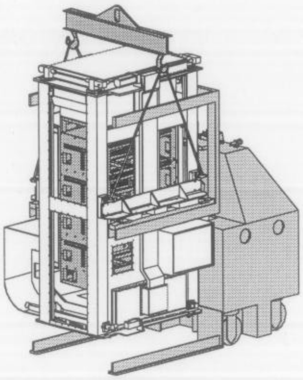

Figure 1. Graphical representation of the delivery systems being developed by Transport and Handling to deliver, retrieve and insert the LRUs into the NIF laser.

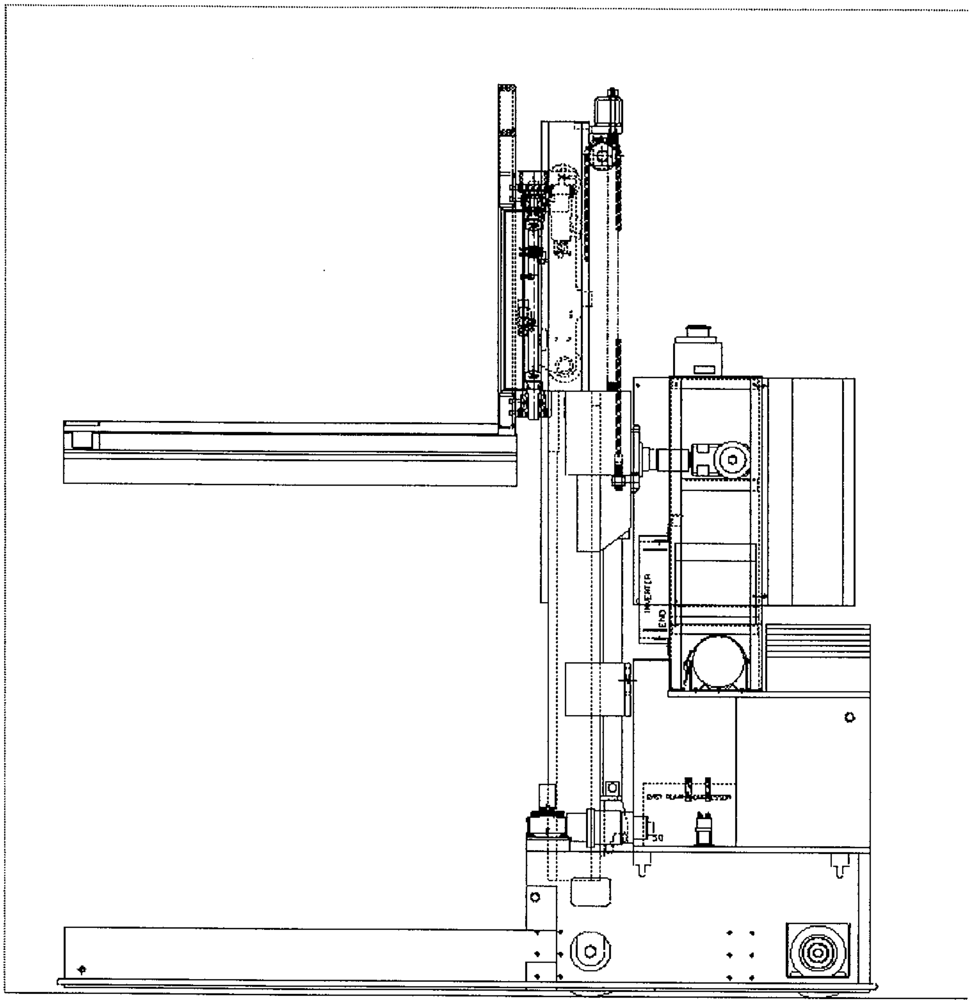

Figure 2. Side schematic view of the Laser Bay Transporter (LBT) showing the main body on the right, the outrigger legs on the left and the forked platform raised to about 80% of its maximum-lift height.

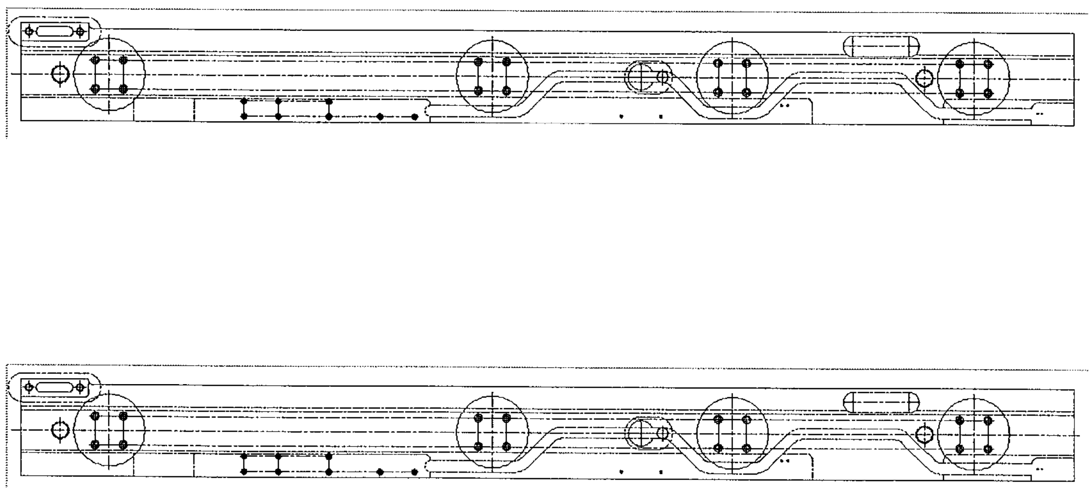

Figure 3. The interface plates, which mount to the top of the Laser Bay Transporter (LBT) forks, provide a common interface for bottom, side and top loading operations. Conical-pin mounting-receptacle areas are shown. The four end receptacles are for the bottom-loading canister, the middle two are for the top-loading canister and the second set from the right edge is for the side-loading skid.